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Insulation and Ventilation OF ANIMAL SHELTER BUILDINGS

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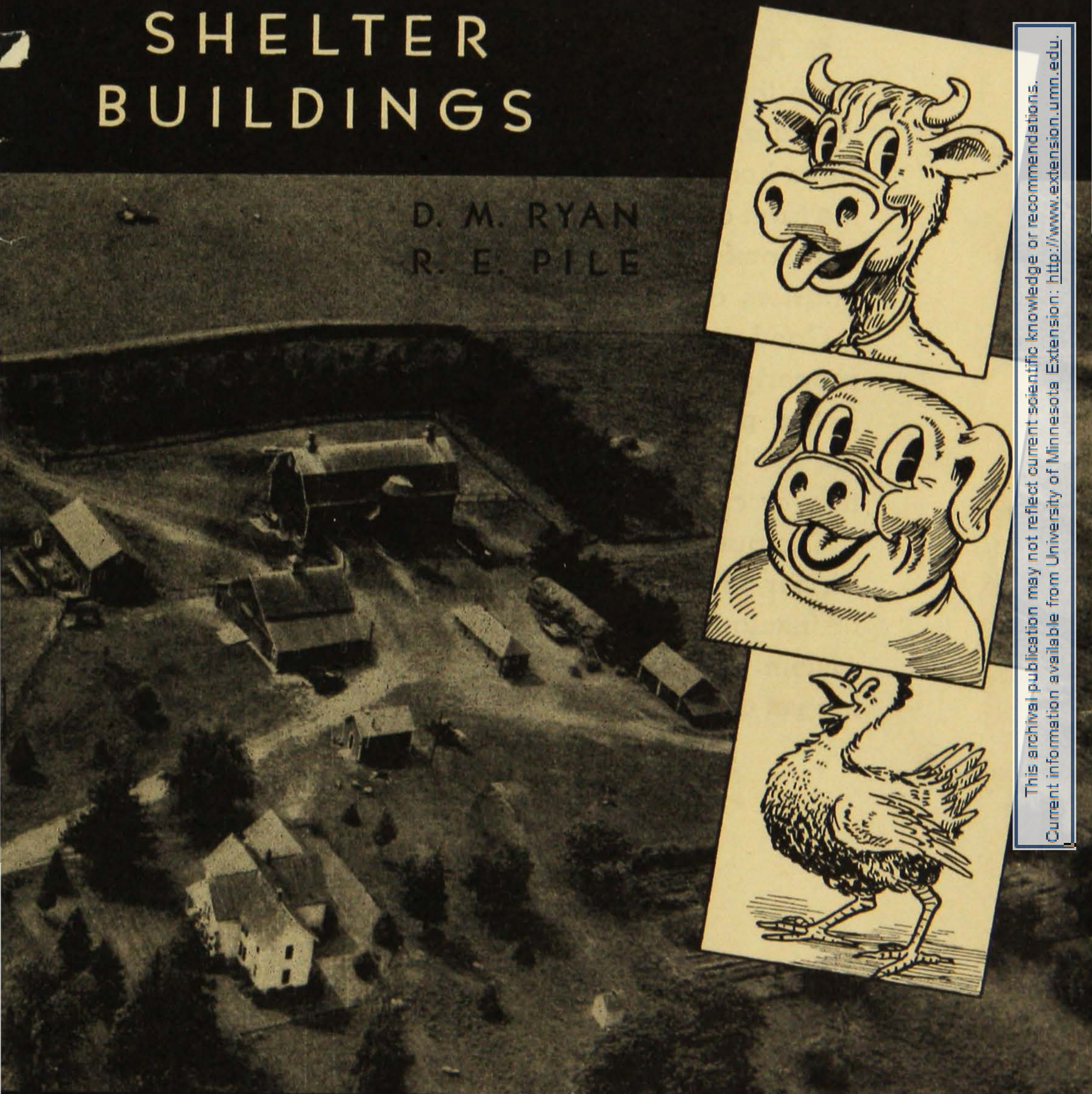

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Agricultural Extension Service
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● A good animal shelter building does more than merely provide protection from the rain, snow, sun, and wind. It also insures healthful indoor living conditions for the farm animals. Experiments have shown that comfortable animals kept in healthful quarters are the most efficient producers.

Good insulation and ventilation, when properly installed, will not only make for better production but will also lengthen the life of the building by preventing rotting or crumbling.

The purpose of this bulletin is to help the farmer in selecting the type and amount of insulating material and the ventilation system that applies to his particular building set-up.

Insulation and Ventilation of Animal Shelter Buildings

D. M. RYAN and R. E. PILE

HOW many poultrymen find wet litter and frost-covered walls and ceiling on a cold winter morning?

How many dairymen find damp stable walls when the temperature takes a sudden dip below zero?

How many hog producers on a typical February morning find frost-laden windows that drip down onto bedding in the pens when the sun comes out?

To control the moisture and temperature in farm buildings, insulation, vapor barriers, and ventilation are essential parts of construction. Each of these factors will be discussed in this bulletin to show the farmer their importance in the sound construction of animal shelters.

Insulation

Insulating material is used to slow up the passage of heat. In winter it helps to hold the heat within the building, and in warm weather it tends to prevent the heat from entering the structure.

A "dead" air space is the best type of insulation. To qualify as "dead" the air must not circulate and must be confined to a relatively small area. Therefore, lightweight materials, not too dense, containing small pockets of entrapped air are the best insulators. This factor can be noted in table 1 by comparing the heat-resistance values of both construction and insulating materials. Fill insulation has the highest insulating value because it has the most tiny "still" air spaces.

There are two kinds of insulation, namely (1) manufactured insulation and (2) farm-processed insulation. Manufactured insulation is usually available in rigid, semirigid, flexible, and loose-fill forms.

Manufactured Insulation

Rigid Insulation—Insulating building board may be used as a combination insulating and structural material, such as sheathing, plaster base, or interior finish for walls and ceiling. It is produced in panels of various sizes and can be sawed and nailed.

Semirigid Insulation—Semirigid insulation sections are commonly called "felts." They are primarily used as insulation since they do not possess structural strength.

Flexible Insulation—Flexible insulation is usually referred to as blanket-type insulation. It is generally placed between studs and other framing members in walls and roofs.

Fill Insulation—Fill insulation is granulated, shredded, or powdered material. This type may be obtained in bulk lots or in the form of "batts." The insulating value of fill insulation varies with the thickness and density when installed.

Farm-Processed Insulation

Farm by-products make satisfactory loose-fill insulation if properly installed. Success with these materials depends upon thickness used, dryness when installed, and precautions taken to keep insulation free from moisture. Chopped flax straw, chopped wheat straw, and planer shavings are the most effective home-processed insulating materials. Sawdust and ground corn cobs are sometimes used, but they are not too effective because they absorb moisture readily and settle too much.

To keep rats, mice, and other vermin from home-processed insulation, mix either powdered slaked lime or used crankcase oil with the insulating materials.

Insulating Properties of Materials—Table 1 gives the internal heat-resistance values of various materials. Figures 3 to 6 show the insulating values for various combinations of materials. The highest numbers indicate the greatest insulating value.

A ¾-inch air space has the same insulating value as the space in walls framed with 2 x 4 or 2 x 6 inch studs. Such spaces are considered equal and are equivalent to ¼ to ⅓ inch of average insulating material. Although build-

Table 1. Internal Heat-Resistance Value of Materials

Material	"Internal resistance" based on sample 1 foot square, thickness as shown	
	Thickness in inches	"R"*
Air space—as used in building construction	¾ or more	.91
Brick, common	4	.80
Concrete—150 pounds per cubic foot	10	.84
Cinder concrete—110 pounds per cubic foot	10	1.90
Concrete block—sand, gravel	8	1.00
Cinder concrete block	8	1.61
Hollow tile—one cell	4	1.00
Hollow tile—two cell	8	1.67
Hollow tile—three cell	12	2.50
Wood ceiling	9/16	.70
Drop siding	¾	.94
Sheathing or flooring	1	.98
Shingles		
Asbestos	......	.17
Slate	......	.10
Wood	......	.78
Stone	16	1.28
Rigid insulating board	1	3.03
Semirigid insulation	1	3.12
Flexible—blanket type	1	3.70
Fill insulation		
Fluffy rock or mineral fiber	3⅝	12.10
	5⅝	18.75
Planer shavings	3⅝	8.85
	5⅝	13.70
Chopped flax or wheat straw	3⅝	6.9
	5⅝	10.7

* R values are "internal resistance" and represent the degree difference in temperature on opposite surfaces of a material of thickness stated which will cause 1 B.T.U. of heat to pass through an area of 1 square foot in 1 hour.

ing paper has practically no insulating value, it saves heat by covering cracks and preventing air leaks.

How to Calculate the Amount of Insulation Needed—Insulation for animal shelter buildings has been recognized as essential to the functioning of a ventilation system. An animal supplies a certain amount of heat. A portion of the heat is given off in the form of vapor which cannot be used for heating the building. Another portion is lost by ventilation to remove the moisture necessary to maintain a desired humidity. The remainder of the heat can be used to keep the building warm. The amount of insulation required to restrict losses through the walls, ceilings, doors, and windows can be calculated in order that the usable heat will maintain a selected temperature within the shelter. The insulation depends on the radiation area in square feet in relation to type and number of animals.

Figures 1 and 2 can be used to calculate the average insulation needed for a given radiation area and number of animals. The values shown were computed from the following data: Outside temperature −15° F., inside temperature 45° F., relative humidity 75 per cent.

Example—The following illustration is based on a 60- by 34-foot stable with 22 cow stalls, one bull pen, and three calf pens. It is assumed that the calves will furnish heat equivalent to one cow.

Column A is the area in square feet through which heat is lost. This area is computed by multiplying in feet the length by the width or height of the ceiling, side walls, end walls, windows, and doors.

Column B is the insulating value for each type of construction listed. These values are illustrated in figures 3, 4, and 6.

Column C is calculated by dividing column A by column B.

Radiation area is the sum of all the items in column A. Do not include any area that is below the ground line or against an earth bank.

The average insulating value in the above example is computed by dividing the total in column A by the total in column C, thus: $\frac{3{,}544}{1{,}017} = 3.48$.

The number of animal units in the barn is 24, consisting of 22 cows, one

Table 2. Dairy Stable with Low Insulating Value

	A	B	C	D
	Radiation area in square feet	Insulating value	Heat loss A÷B	Type of construction
Ceiling	2,040	30	68	¾-inch matched flooring, 18 inches of settled hay or straw
Windows	96	0.9	107	Single sash
Doors	90	1.7	53	Single thickness of matched lumber
Foundation	376	1.6	235	10-inch concrete 2 feet high
Walls	942	1.7	554	¾-inch siding, building paper, studs
Totals	3,544		1,017	

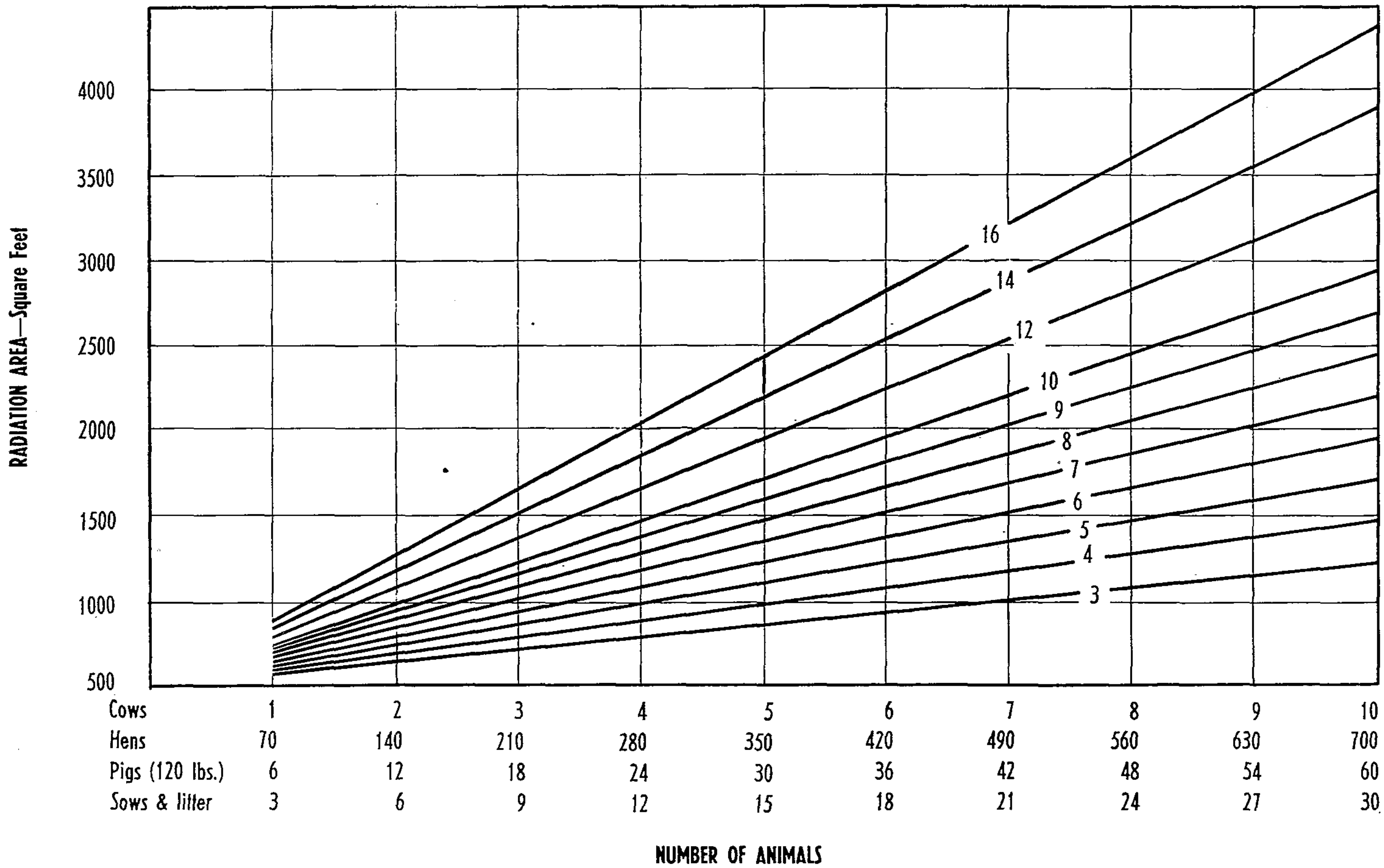

FIG. 1. Slanting lines indicate average insulating value according to number of animals versus radiation area

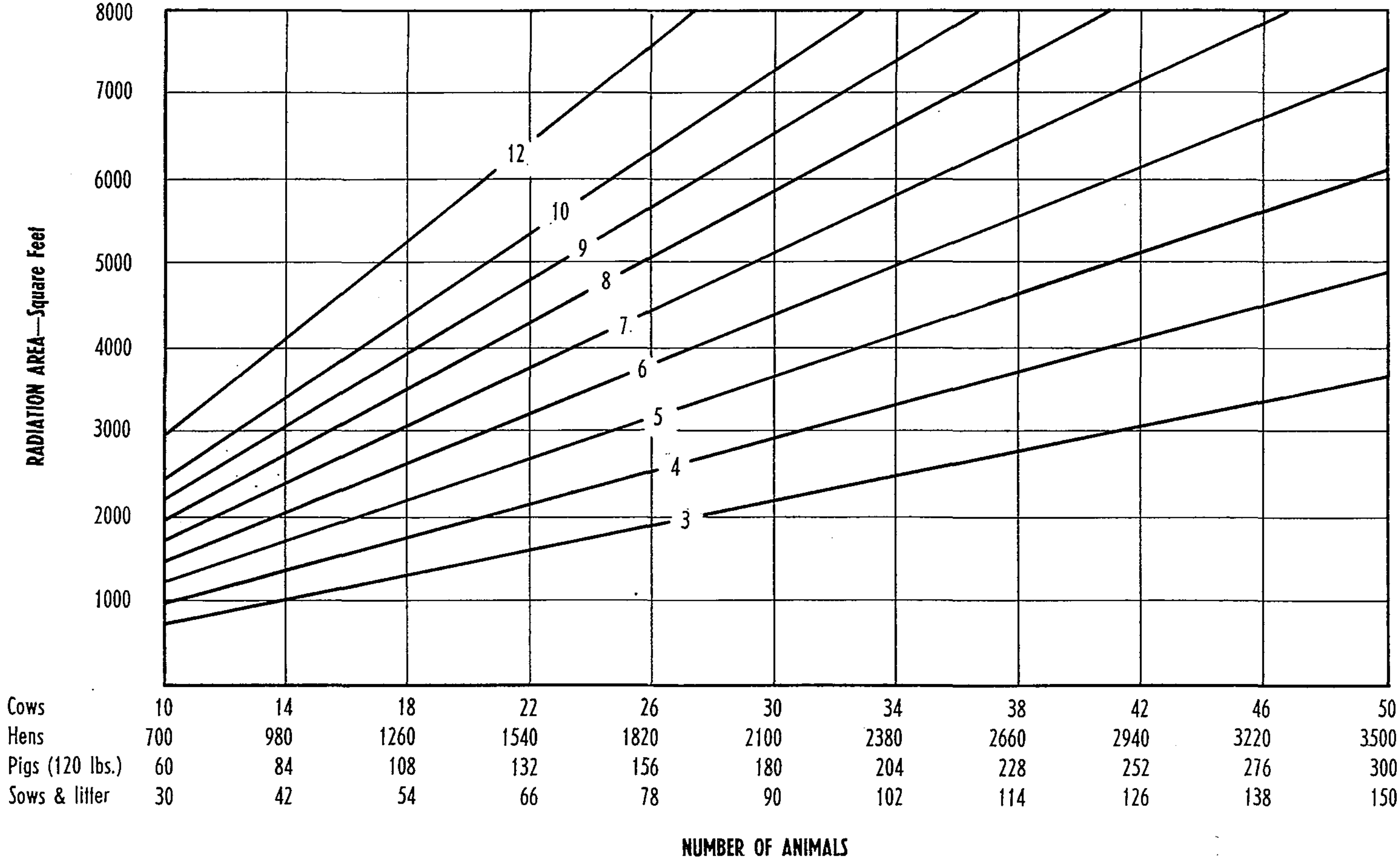

FIG. 2. Continuation of figure 1, for greater number of animals

bull, and calves equal to one cow. Referring to figure 2, 3,544 square feet of radiation area can be located on the left side about half way up; likewise 24 cows can be located along the bottom. By drawing lines across and upward from these values it will be noted that they cross on slanted line 6, which is the average insulating value needed in this particular barn.

Since the calculated insulating value of 3.48 is much lower than the required value of 6.0 (determined by figure 2), it will be necessary to add insulation to the existing structure. A comparison of tables 2 and 3 shows that additional insulation was added to the structure by using double-matched lumber with paper between for doors, and by placing 3⅝ inches of planer shavings between stud spaces in the walls covered with vaporproof paper and ¾-inch matched boards.

The stable insulation now becomes $\frac{3,544}{525} = 6.75$. Since the insulating value of 6.75 is greater than the required value of 6.0 obtained from figure 2, the barn now has adequate insulation.

Similar calculations for poultry laying houses show that a 60-degree temperature difference can be maintained with either a 6-inch fill of farm-processed insulation or a 4-inch fill of manufactured insulation. It cannot be maintained, however, if the house is lined only with insulating board or similar sheathing material.

This method can also be applied to centralized hog houses to determine the insulation needed to maintain a comfortable temperature within the shelter during cold winter weather.

How to Read Insulation Diagrams— Insulating values for various types of building construction are illustrated in figures 3 to 6. The combination of materials that gives the highest insulating value has the longest bar on the right-hand side. The numerical value for each bar is given for use with tables 2 and 3 when calculating the insulating value of any animal shelter.

Table 3. Dairy Stable with Adequate Insulating Value

	A	B	C	D
	Radiation area in square feet	Insulating value	Heat loss A÷B	Type of construction
Ceiling	2,040	30	68	¾-inch matched flooring, 18 inches of settled hay or straw
Windows	96	0.9	107	Single sash
Doors	90	2.7	33	Double-matched lumber with paper
Foundation	376	1.6	235	10-inch concrete 2 feet high
Walls	942	11.5	82	¾-inch siding, building paper, 3⅝-inch stud space filled with planer shavings, vaporproof paper, ¾-inch matched boards
Total	3,544		525	

Type of construction	Insulating value
Drop siding, building paper, studs	1.7
Lap siding, building paper, sheathing, studs	2.5
Drop siding, building paper, studs, sheathing	3.5
Drop siding, building paper, studs, ½-inch rigid insulation board	4.1
Drop siding, building paper, studs, 1-inch rigid insulation board	5.5
Drop siding, building paper, studs, 1-inch blanket insulation between studs, sheathing	8.1
Drop siding, building paper, 4-inch studs, space filled with chopped wheat or flax straw, vaporproof paper, sheathing	9.5
Drop siding, building paper, 4-inch studs, space filled with wood shavings, vaporproof paper, sheathing	11.5
Drop siding, building paper, 6-inch studs, space filled with chopped wheat or flax straw, vaporproof paper, sheathing	13.3
Drop siding, building paper, 4-inch studs, space filled with commercial fill insulation, vaporproof paper, sheathing	16.0
Drop siding, building paper, 6-inch studs, space filled with wood shavings, vaporproof paper, sheathing	16.4
Drop siding, building paper, 6-inch studs, space filled with commercial fill insulation, vaporproof paper, sheathing	22.7

FIG. 3. Insulating values of various types of frame wall construction

Type of construction	Insulating value
8-inch solid concrete wall	1.4
8-inch solid concrete wall, furring strips, plaster on 1-inch insulation board	5.5
10-inch solid concrete wall	1.6
10-inch solid concrete wall, furring strips, plaster on 1-inch insulation board	5.7
Double 4-inch concrete, 2½-inch fill insulation between	8.1
16-inch solid stone wall	2.0
16-inch solid stone wall, furring strips, plaster on 1-inch insulation board	6.1
8-inch hollow tile	2.5
8-inch hollow tile, furring strips, plaster on 1-inch insulation board	6.6
12-inch hollow tile	3.3
12-inch hollow tile, furring strips, plaster on 1-inch insulation board	7.4
Double 4-inch hollow tile, at least 1-inch air space between	3.7

FIG. 4. Insulating values of various masonry wall constructions

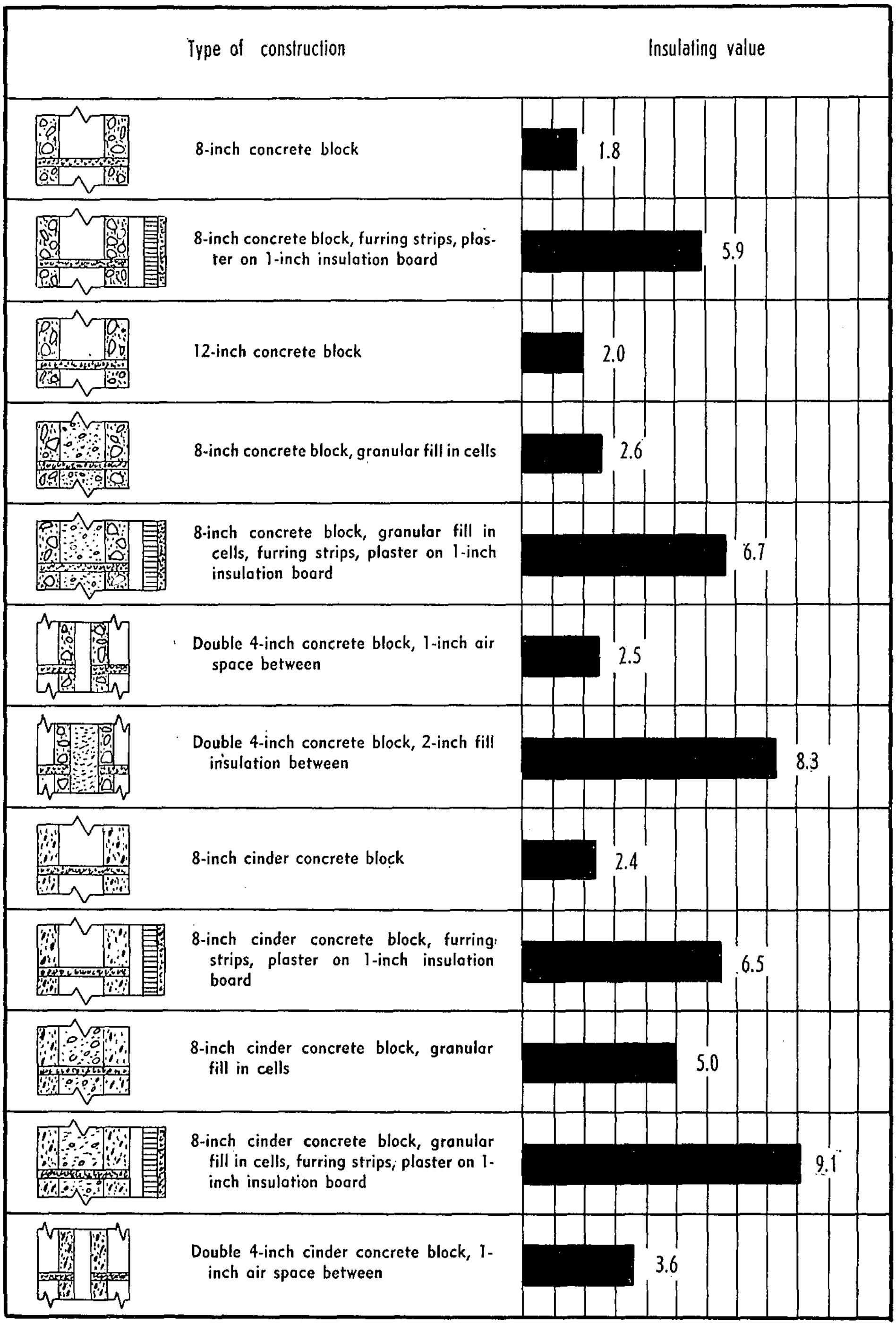

FIG. 5. Insulating values of various masonry wall constructions

Type of construction	Insulating value
CEILINGS	
Vaporproof paper and ¾-inch matched flooring on top of ceiling joists	2.2
Vaporproof paper, ¾-inch matched flooring on top of ceiling joists, and covered with one foot of settled hay or straw	30.0
Attic joists ceiled on lower side by vaporproof paper and ¾-inch matched flooring; space between joists filled with 6-inch dry wood shavings	15.7
Attic joists ceiled on lower side by 1-inch vaporproof insulation board	4.2
PARTITIONS	
Single thickness matched lumber (sheathing)	2.2
Matched lumber (sheathing) on both sides of studs	4.1
DOORS AND WINDOWS	
Outside door ¾-inch matched lumber	1.7
Outside door two layers ¾-inch matched lumber with vaporproof paper between	2.7
Ordinary window sash	0.9
Storm-sashed windows	2.2

FIG. 6. Insulating values of various ceiling, partition, door, and window constructions

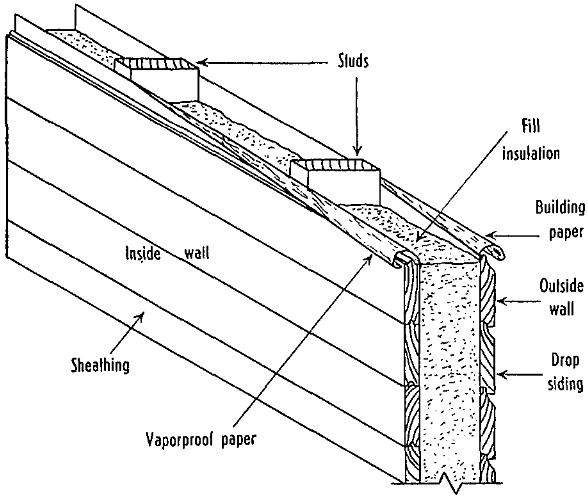

FIG. 7. View of frame wall construction showing vapor barrier and fill insulation

Figure 7 illustrates the placing of a vapor barrier. A vapor barrier should not be placed on the outside wall. If insulation becomes partially damp it should be allowed to breathe itself dry, and a vapor barrier placed on the outside wall would prevent this.

Vapor Barriers

All air contains water in the form of vapor. This vapor accumulates within animal shelters until there is enough pressure to force the vapor through the walls and ceilings. Vapor will pass through materials that air will not. Especially in an insulated structure it tends to filter through walls where it condenses into water when it strikes a cold surface. This is very likely to happen in farm buildings where relative humidities are high and there is a considerable temperature difference between inside and outside. The walls or ceiling materials then become damp, and water may collect in the insulating materials to such an extent that insulating value is appreciably reduced and may even cause building members to deteriorate or paint to peel. Condensation within walls can be prevented by applying vapor barriers—materials which are highly resistant to passage of vapor—to the interior surfaces of walls and ceilings.

Ventilation

Good ventilation does four very important things: provides adequate moisture removal; minimizes temperature variations inside the barn; properly circulates air; and removes foul odors. The hardest problem is removing moisture and holding relative humidity at a comfortable figure. The biggest contributing factor to a satisfactory ventilation system is adequate insulation. Sufficient insulation will maintain a great enough difference between inside and outside temperature so that the ventilation system will operate efficiently.

Following the recommended average insulating values for animal shelters, the minimum allowable volume of air change under restricted ventilation for each class of animal is as follows: *(Based on humidity of 75 per cent and inside temperature of 45° F. when it is —15° F. outside.)*

Cow—20 cubic feet of air per minute

Sow and litter—7½ cubic feet of air per minute

Swine (120 pounds)—4½ cubic feet of air per minute

Hen—¼ cubic foot of air per minute

Obviously this volume of air change will not be enough when the weather is mild. It is necessary to set also the upper limits of air requirements in order to specify the maximum capacity of the ventilation system.

When outside temperature rises to

30° F. it will be difficult to maintain a constant inside temperature of 45° F., because the required air movement would cause drafts. It is possible, however, to hold a temperature difference of 25 degrees and permit the inside temperature to rise to 55° F. under such mild conditions. To increase ventilation when temperature rises above freezing, doors and windows may be opened. The maximum capacity of the ventilation system should supply air movement for each class of animal as follows:

Cow—70 cubic feet of air per minute

Sow and litter—26 cubic feet of air per minute

Swine (120 pounds)—15 cubic feet of air per minute

Hen—1 cubic foot of air per minute

Note that the amount of air movement required in mild weather is approximately 3½ times the minimum allowable when it is −15° F. outside. It is therefore recommended that a ventilation system planned to meet the maximum conditions be so constructed that it can be throttled down to restricted capacity when the outside temperature reaches −15° F.

A good ventilation system provides a definite intake for air to enter the shelter and a definite outtake through which the moisture-laden air may escape. Leaks and cracks should be eliminated to make the system function efficiently. All intake and outtake flues should be constructed with adjustable openings. It is not possible to lay down a definite set of directions that will handle all the variables in every system. Some personal attention and sound judgment based on experience will determine how efficiently the system will operate.

Intakes

Intakes usually follow the same general pattern regardless of method of outtake. This discussion on intakes applies to all ventilation systems.

The cross-sectional area of a standard size intake is usually 60 square inches. This would mean an inlet 4 by 15 inches, 3 by 20 inches, or 6 by 10 inches.

A drop in the outside temperature will ordinarily cause more rapid movement of air into and out of the shelter and consequently a lowering of inside temperature. To correct this, the area of each intake opening should be gradually reduced. If a high wind accompanies the drop in temperature a greater reduction in intake area should be made. Any intake found to be back drafting should be closed. If the inside temperature does not then remain normal it may be advisable to close all inlets on the windward side.

Window ventilation is desirable in moderate weather but is unreliable during cold windy weather. The windows might act as outtakes rather than intakes. Drafts may be caused by not properly regulating the windows. Where tip-in windows with side shields are used it may be advisable to place a vertical board at the top of the window to direct the incoming air straight up to the ceiling. The upper part of the board should not come closer than 12 inches to the ceiling. Considering the usual width of animal shelter windows, a tip-in distance of about 2 inches is generally adequate.

Number of Intakes—The number of intakes is related directly to the amount of outgoing air regardless of the type of system used; therefore, the basis for determining the number of intakes is:

Dairy barn—one intake per 3½ cows

Poultry house—one intake per 125 square feet of floor space

Hog house—one intake per two farrowing pens

Location of Intakes:

1. Distribute intakes evenly around the shelter to provide good circulation of air at all points.
2. Don't locate intakes under poultry roosts.

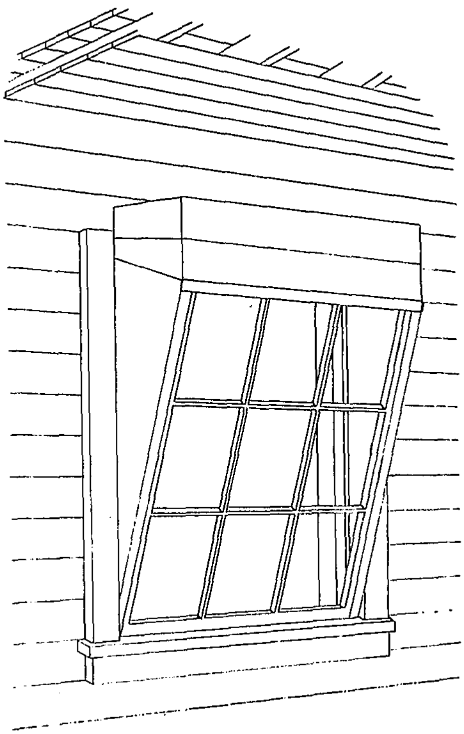

FIG. 8. View of tip-in window inlet, showing side shields and deflection boards for directing incoming air toward the ceiling. Top of deflecting board should be a minimum of 12 inches below the ceiling.

3. Locate intakes at least 8 feet from the corner of the building, measuring to center of intake.
4. Locate intakes at least 6 feet from a natural draft outtake.
5. Locate intakes at least 12 feet from exhaust fans.
6. Locate intakes at least 6 feet from thermostats.

Construction of Intakes—The outside entrance of intakes should be above the snow line and where possible should be 5 feet below the inside openings. If this arrangement places the inside openings closer than 12 inches to the ceiling, the 5-foot interval will have to be reduced. The greater the distance between inside and outside openings the less chance that warm air which is trapped at the ceiling will back draft through the inlets. Many commercial companies manufacture specially constructed intakes with automatic devices to prevent back drafts.

All intakes should be insulated to prevent sweating. It is advisable to have all incoming air directed upward. Figure 9 shows how air is brought into a building, depending on type of construction.

The inside openings should have a sliding damper or a hinged cover so that the volume of incoming air may be restricted on very cold or windy days. The outer opening should be screened with hardware cloth no smaller than ½-inch mesh but small enough to keep out birds and rodents.

Outtakes

The various types of outtake systems used in Minnesota for different classes of livestock are:

Dairy
1. Vertical stacklike flue
2. Fan system

Swine
1. Vertical stacklike flue
2. Fan system
3. Straw loft
4. Front window flush with ceiling

Poultry
1. Vertical stacklike flue
2. Fan system
3. Straw loft
4. Front window flush with ceiling
5. Cross hall vent or cross trough vent

VERTICAL STACKLIKE FLUE

Vertical flues work best in cold weather in an adequately insulated shelter which maintains a big difference between inside and outside temperature. The height of the flue has a bearing on the successful removal of moist, foul air. Ordinarily the flue starts 12 to 18 inches from the floor in an insulated building and is con-

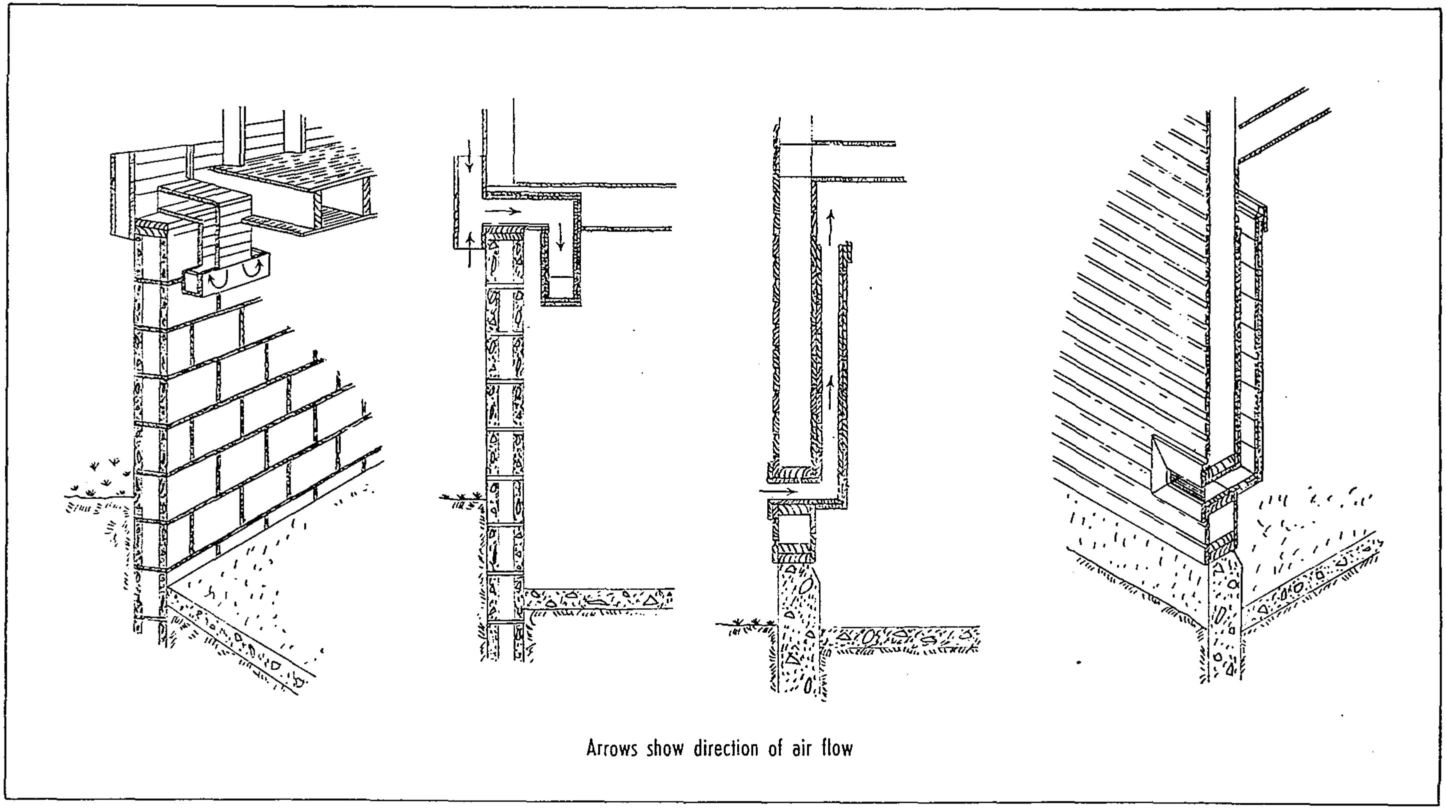

FIG. 9. Two methods of installing inlets. The two views at the left show an inlet for masonry wall construction. The two views at the right show an inlet for frame wall construction.

structed upward to a point two feet above the ridge. In an uninsulated building the air should be removed at the ceiling. Twenty feet is the minimum height flue recommended. This means a flue may have to be constructed 8 or 10 feet above the roof in a shed roof shelter. A sliding damper should be installed on all flues to regulate the air outtake. Owing to the probability of ice collecting on the inside of the outtake flue when partially closed, it might be preferable to close one outtake entirely rather than all of them part way.

Openings should be made in the outtakes near the ceiling to permit the rapid removal of warm air during mild weather. Outtake flues should be constructed as straight as possible. A roof over the top of a flue is desirable to avoid down drafts. The outtake must be insulated, including the roof that is placed over the top.

Flues in poultry and hog houses usually are located near the center line of the building. In dairy barns the flues may be constructed on the sides. Figure 10 illustrates different positions where flues may be placed. Table 4 gives the flue area in square inches necessary to remove required air for number of animals in shelter according to respective heights of flues. Flues are usually arranged in pairs, but the exact number of outtakes depends on the number and arrangement of animals in the shelter. Regardless of number used, the total area of all the outtakes should equal the area shown in table 4, according to number of animals and flue heights for any specific shelter.

It is advisable not to use less than two 12-inch square flues for any building. Two 12-inch square flues have an area of 288 square inches, which is the smallest area shown in table 4.

FAN SYSTEM

Fans are used in this system instead of outtake flues to remove required air from the animal shelter. They are usually placed in the wall and blow air directly outside. The fans may be equipped with variable or automatic speed controls to regulate the amount of air removed. In order to get graduated air control in designing electric ventilation systems, two or more fans, each controlled by a separate thermostat and hand switch, are recommended. In this way only can any degree of automatic air control be secured because of the variation in number and size of animals kept in the building at different times. In moderate weather both fans should operate. In severe weather one can be turned off and the thermostat set at the desired minimum temperature for the operation of the other.

In an electrical system the fan should be located near the ceiling. It is optional either to remove air at the ceiling or 12 to 18 inches from the floor by means of a flue that encloses the fan and extends down toward the floor.

In a natural draft system, gravity furnishes the motive power. The cold air outdoors, heavier per cubic foot

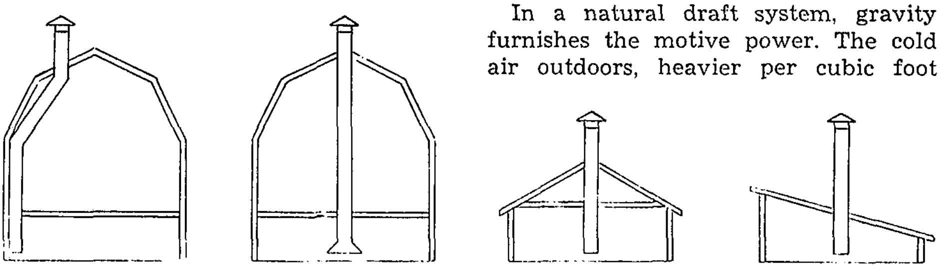

FIG. 10. Illustrations showing different positions of outtake flues

Table 4. Size of Outtake Flue Areas in Square Inches

Number of animals in shelter				Cross section area needed for various heights of flue					
Cows	Sow and litter	Pigs (120 lbs.)	Hens	20 feet	25 feet	30 feet	35 feet	40 feet	45 feet
				Square inches					
2	6	12	140	288	288	288	288	288	288
3	9	18	210	288	288	288	288	288	288
4	12	24	280	288	288	288	288	288	288
5	15	30	350	288	288	288	288	288	288
6	18	36	420	288	288	288	288	288	288
7	21	42	490	332	295	288	288	288	288
8	24	48	560	380	338	307	288	288	288
9	27	54	630	428	380	346	321	301	288
10	30	60	700	475	422	384	357	334	315
11	33	66	770	522	464	422	393	367	346
12	36	72	840	570	507	461	428	401	378
13	39	78	910	618	549	499	464	434	410
14	42	84	980	665	591	538	500	468	441
15	45	90	1,050	713	633	576	536	501	472
16	48	96	1,120	760	675	614	571	534	504
17	51	102	1,190	808	718	653	607	568	536
18	54	108	1,260	855	760	691	643	601	567
19	57	114	1,330	903	802	730	678	634	598
20	60	120	1,400	950	844	768	714	668	630
22	66	132	1,540	1,045	929	845	786	735	693
24	72	144	1,680	1,140	1,013	922	858	801	756
26	78	156	1,820	1,235	1,097	998	929	868	819
28	84	168	1,960	1,330	1,182	1,075	1,000	935	882
30	90	180	2,100	1,425	1,266	1,152	1,071	1,002	945

NOTE: For greater number of animals, increase flue area in direct proportion to increase in animals. Example: Area for 40 cows equals area for 30 cows plus area for 10 cows.

than the air indoors, forces its way through the intakes and pushes out the warm air. The greater the difference in temperature, the harder it pushes and the faster the air change. In a gravity system the floor outtake acts as a brake on the air change at the time when a brake is essential.

In an electric system outside temperature is not a power factor. A fan will exhaust warm air or cold air with equal facility. It might be desirable to remove the air at the ceiling because there is a greater accumulation of moisture at the ceiling than at the floor—so much greater that for each unit of heat lost through exhaust from near the ceiling, more moisture is driven out than for a similar heat loss through air taken from near the floor.

To safeguard the fan from weather and to prevent back drafting, it is necessary that fan openings in the wall be protected by hooded exhaust louvers that will close automatically against incoming air pressure but will open readily when the fan goes into action.

To determine the number of fans needed, use the quantities of air calculated on page 13 for maximum conditions of ventilation for each type of animal.

The capacities of fans of the same diameter vary, depending on the speed and number and design of blades. The values in table 5 are given as a guide in selection of fan size. It is desirable to check with the company installing the system as to actual performance of its particular type of fan.

Table 5. Capacity and Performance of Fans

Approximate diameter of fan	H.P.	Cubic feet of air per minute against 18-mile wind
10	1/6	500
12	1/6	1,000
16	1/6	2,000

How to Select Number and Size of Fan—What number and size of fans are needed to remove required air from a stable which shelters 16 cows, six heifers, and five calves? Heifers and calves are figured on the basis of 1,000 pounds total weight being equivalent to one cow. Six heifers are equivalent to three cows. Five calves are equivalent to one cow. The total design units equal 16 plus 3 plus 1 or 20 cow units.

Each cow unit requires 70 cubic feet of air per minute. $20 \times 70 = 1{,}400$ cubic feet of air per minute for all animals. Referring to table 5, select one 10-inch fan and one 12-inch fan. They will move 1,500 cubic feet of air per minute when used together. It is desirable to place one fan on each side of the barn. During mild weather they both will operate. During extremely cold weather probably only the 10-inch fan will operate continuously.

STRAW LOFTS

Straw lofts may be used in either poultry or hog houses. In this system straw placed in the ceiling is used both as insulation and as a medium for warm moist air to filter through before reaching the outside by means of large doors cut in each end of the gable. The doors should be 2½ feet by 3 feet. If the building is more than 25 feet long, a 12-inch square roof vent should be installed per 10 feet of additional length.

A minimum of 2 feet of straw should be placed on ceiling boards spaced 1 inch apart. At the point where the ceiling and roof are 2 feet or less apart the ceiling should be boarded solid and at least 6 inches of good insulating material should be placed over the solid part of the ceiling.

The doors and vents above the straw should never be closed. The temperature within the shelter should be regulated by depth of the straw.

For discussion and plans on straw loft construction see Extension Bulletin 121, "Poultry Housing"—obtainable from Bulletin Room, University Farm, St. Paul 1, Minnesota.

FRONT WINDOW VENTILATION

In a well-insulated shed roof poultry or hog house, front window ventilation has produced reasonably good results.

The front windows are hung on pivots at the sides so that they tip out at the top and in at the bottom. The top of the window should be flush with the ceiling.

One window 16 inches deep by 30 inches long should be installed for every 125 square feet of floor space. The number needed was calculated on a basis that each window would be tipped out 3 inches at the top and tipped in 2 inches at the bottom. To maintain this proportion between outlet and inlet air, the pivots on which the window is hung can be installed about one inch below center. It is advisable to install windows in center of outside wall.

CROSS HALL VENT OR CROSS TROUGH VENT

This system applies to poultry houses only. In the cross hall ventilation system a hall 3 feet wide is built across the middle of the poultry house. Dutch doors, flush with the ceiling, open off each end of the hall to the outside. An opening 6 to 8 inches deep and about two thirds the width of the house is cut out of each side of the hall. This opening is made at the top of the hall wall and in the center two thirds of the house. As fresh air comes in the inlets, the foul air escapes through these openings into the hall and out through the Dutch doors which are regulated according to temperature and direction of wind. Except in extreme weather conditions at least the top part of one Dutch door should remain open. If it is necessary to close the top and bottom of both doors, the air can escape through an opening in the center of the hall up into the loft and out through louvers at each end of the gable. The opening into the loft should have a trap door regulated by a pulley and rope. This opening should be closed when the Dutch doors are open.

The side walls and ceilings of both the poultry house proper and cross hall should be adequately insulated. This system requires some experience in adjusting doors and openings according to changes of temperature and wind.

In the cross trough ventilation system a trough 3 to 4 feet wide and about 1½ feet deep is substituted for the hall vent. It is built across the center of the house and has the same openings as the hall. A sliding door operated by pulley and rope can be substituted for Dutch doors to regulate the openings leading to the outside at the ends of the trough.

Remember the most important part of the functioning of any ventilation system is adequate insulation to maintain a large enough difference between inside and outside temperature.

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